

Current Advances in Strategies to Mitigate the Impacts of Micro/Nano Plastics: A Review

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Abstract

With the increasing demand for and reliance on plastics as an everyday item, and rapid increase in their production and subsequent indiscriminate disposal, the environmental implications of plastics are of growing concern. Given that plastic polymers are highly resistant to degradation, the influx of these persistent, complex materials is a risk to human and environmental health. Microplastics is described as a truly heterogeneous mixture of particles ranging in size from a few microns to several millimetres in diameter; including particles of various shapes from completely spherical to elongated fibres. Microplastic pollution has been reported on a global scale from the poles to the equator. The main route of concern is currently as a consequence of ingestion, which could lead to physical and toxicological effects on aquatic organisms.

To this end, in order to minimize the negative impacts posed by plastic pollution (microplastics), a plethora of strategies have been developed at various levels to reduce and manage the plastic wastes. The main objective of this paper is to review some of the published literatures on management measures of plastic wastes.

Keywords: Polymers; Plastic pollution; Aquatic organisms; Microplastic

Introduction

Plastic pollution has been a menace to our society for decades due to continued rise in human population combined with consumption, degradation through abiotic and oceanic factors (fragmentation due to Ultraviolet radiation, mechanical abrasion) and their wide applications in every human endeavours; packaging, agriculture, automobiles, biomedical, telecommunication, building and construction, furniture, plumbing works, transportation, etc. [1-5]. This is clearly evident in the Great Pacific Garbage Patch, a ring of marine litter, containing large amount of plastic wastes, in the central North Pacific Ocean located between 135-155°W and 35-42°N [6]. Plastics are still in high demand in this modern era to improve the quality of life but undoubtedly have changed the way we live [7]. In coastal areas, the marine pollution of plastic is increasing at alarming rate due to indiscriminate disposal by the consumers (beach visitors, tourists, shipping/maritime companies, fishery operators, etc.) [8]. Records have shown that on a global scale, over 300 million metric tons of plastics are produced annually out of which 50% of this are disposed indiscriminately into the environment and about 4.8-12.7 million tons end up in marine ecosystem (water column, sediment and biological tissues) as microplastics (plastic materials <5mm), arising from degradation of larger plastic litter [9-13]. It is estimated that by 2050, an extra 33 billion tonnes of plastic will be added to the planet. Plastics are ubiquitous in the environment in a wide variety of sizes ranging from meters to micrometers and have different routes of entering into various compartments of marine food-webs [3,14,15]. Although, the societal benefits of plastics are enormous, there are some environmental concerns associated with the material [7,16]. For instance, the potential deleterious effects from ingestion, have elevated the urgency to evaluate the impact of plastics on the whole marine food chain and, ultimately, the consequences for humans as end consumers [17-19]. Wegner et al. and Von Moos et al. [20,21] reported an increased pseudo-faecal deposit, reduced filter-feeding activity and inflammatory response of blue mussel (*Mytilus edulis*) after exposure to 30 nm nanopolystyrene particles. Higher trophic level organisms (e.g marine mammals) are not left out and have been found to ingest microplastics transported by prey items. Microplastic

particles approximately 1 mm in diameter were recorded in the scat of fur seals and Hooker's sea lions [22]. Presently, concerted efforts are geared by the scientists to investigate the toxic exposure of human to plastic debris (microplastics) consumed or ingested by aquatic biota, fish, crustaceans and especially the bivalve molluscs, mussels, oysters, scallops, etc, with particular reference to plasticisers, trace metals, persistent organic pollutants (POPs), stabilizers, which could impair our health after uptake from the seafood, such as disruption of thyroid and sex hormones [13,14,23-26].

To tackle the incidence of negative impacts imposed by microplastics, efficient plastic waste managements that are cost-effective, of high quality performance and eco-friendly, are required and have been a subject of discourse at local, national, regional and international levels [27], due to the non-degradability of plastic wastes and toxicity associated with their leachates. The problem associated with management strategy has to do mainly with lack of scientific knowledge due to limited number of studies [28,29]. To make the situation worse, Seltenrich [30] reported that no formal management plans to mitigate the incidence of microplastics are put in place in some regions of the world. Since the problem of plastic pollution in the ocean originates from land-based activities, it is advisable to resolve the issue from the source (Figure 1).

The main core of this paper is to review some of the current, advanced strategies in reducing the occurrence and menace of microplastics in our environment.

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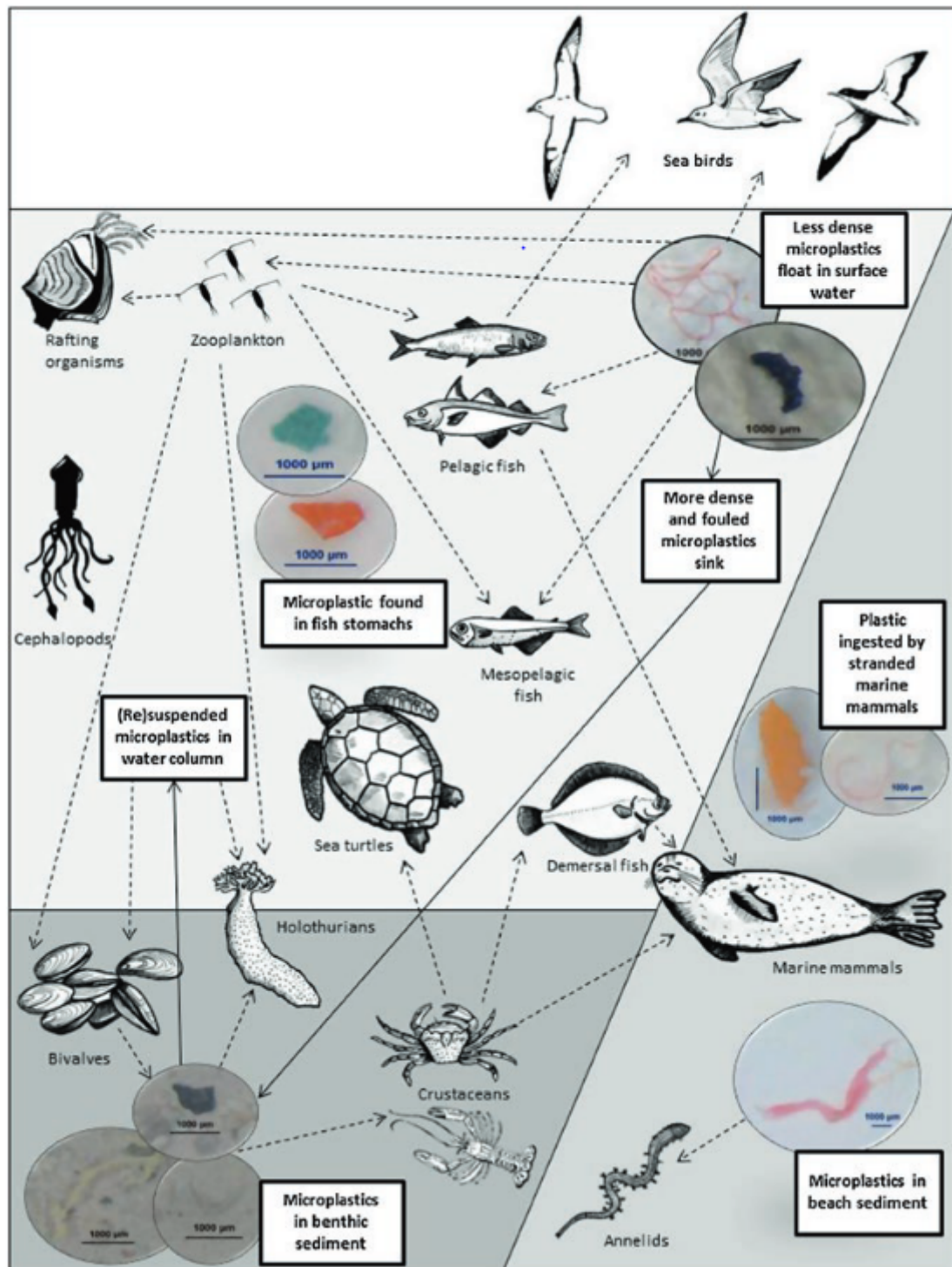


Figure 1: Microplastic interactions in the marine environment including environmental links (solid arrows) and biological links (broken arrows), which highlights potential trophic transfer (Bergmann et al., 2015. Photos of microplastics: A. Lusher).

The Commonly-Used Strategies

While management practices have been directed towards macroplastics worldwide, little attention has been given to microplastics because it is an emerging topic and many people are unaware of its impacts thereby making force change difficult. Although, the

management strategies enumerated here are not exhaustive, they are illustrated as either on a mandatory or voluntary basis and provide a general, snapshot picture of the framework of marine plastic particles.

Preventive and mitigating strategies

Preventive measures focus on the way of avoiding the generation of

debris, or preventing debris from entering the sea. These include source reduction, waste reuse, recycling and composting, waste conversion to energy, debris contained at points of entry into receiving waters and various waste management measures on land [31]. Mitigating measures are concerned with the ways plastic debris are disposed of. These measures are imperative and control regulations, and they overlap with preventive counterparts if they also involve preventing certain types of debris from entering the sea.

Source identification is an invaluable instrument to prevent marine plastic pollution effectively [27]. Microplastics originate from three main sources: land-based, riverine and ocean-based sources [12,32,33]. Walker et al. and Rovira [34,35] reported that ~70-80% of the marine litters found in Halifax Harbour and Chilean mainland coast were land-based origin, which indicate a domestic problem. Pettipas et al. [27] argued that household plastic disposal is not easily regulated due to inadequate resources for auditing and that it is very difficult to trace waste origins in multi-industry areas. They put forward that when common items are identified at the sea or along shorelines or beaches, this can help to establish specific targets and further actions can be taken. Although, mechanical recycling of plastic wastes still remains the most preferable but it imposes high operating cost of sorting, cleaning and separating the polymers [13]. Seltnerich [30] advised that the next generation of plastics could be designed biodegradable (made from carbon dioxide and carbon monoxide compounds and application of metal complexes as catalysts) to reduce their potential of accumulating in the marine environment. This technique provides a double benefit, binding unwanted greenhouse gases, while avoiding the competition with the human food supply. Complete ban or restriction of the use of plastic bags is one of the measures in the reduction of plastic waste. Bangladesh was the first nation to outlaw polythene bags in 2002 followed by Myanmar, China and a number of African countries including Eritrea, Mali, Mauritania, South Africa, etc. [31]. In Canada, it is forbidden to manufacture and sell items containing microplastics except for personal care products [27]. UNCLOS/MARPOL/Honolulu Conventions reiterated complete ban of disposal of plastic wastes at Sea by shipping vessels of all member states and signatories but these regulations are weak due to poor monitoring and surveillance activities and enforcement [36,37].

Removing/Cleaning-Up Strategy

Removing plastic wastes from the beach (termed beach clean-up) and water-column is a measure aims to tidy up the marine environment. It is time-consuming, expensive and only small fraction of the overall debris is captured [38]. Mouat et al. [39] reported that over €18 million is spent each year by the UK municipalities to remove beach debris and this has increased operating cost by 37%.

Behavioral Change Strategy

Educational, outreach and public awareness programmes must be set up by various governmental and non-governmental (NGOs) agencies to promote change (people's behaviour, mentality, orientation and perspective) in order to limit indiscriminate disposal of plastic wastes into the environment [40-42]. The notion that "Change begins with you" at the grass-root levels must be our central focus in environmental management. People should see marine environment not only as common but privately owned property that needs to be protected and well managed. They should stop littering beaches with plastic wastes during visit. Mandatory Ocean and environmental courses must be introduced in our educational curriculum at various levels (primary, high and tertiary institutions). Workshops and projects

on ocean management, conservation and protection must be organised for the students and people at large. Tran [43] reported the importance of involving local populations in various developmental projects as seen in the case of people living in the Island of Holbox (Mexico) who see themselves as integral part and solution to address various environmental problems confronting them. Wiener et al. [44] also reported that the native people of Hawaii showed a very strong interest in adopting traditional ocean conservation measures. Furthermore, Kiessling et al. [8] explained that the people of Rapa Nui (Chile) show greatest concern for coastal litter and waste management in their Island. This strong awareness and willingness of the citizens is traceable to their geographic location, cultural background, biodiversity and economy mainly depends on tourism, therefore, needs to be protected from outside pressure. Public awareness in the use of social media: advertisement, photos, stories, videos, can help to deliver messages quickly to large number of people in their localities [45]. Targeting youth is also seen as an effective way to promote positive behavioural change in people and pursuing marine related careers [46].

Biotechnology (A New Approach)

Biotechnology offers a new potential approach for the management and mitigation of plastic pollution in our environment by using micro-organisms or their components, enzymes, cutinases, lipases, peroxidases, hydrolases, oxido-reductases, to treat and grade plastic wastes. Several species of bacteria, fungi and consortia have been investigated and reported for their potential to biodegrade plastics. These include; various species of *Pseudomonas*, *Flavobacterium*, *Arthrobacter*, *Agromyces*, most of which are soil or sediment dwellers [47]. This can be achieved in combination with other methods such as pre-treatment with temperature, radiation or light (photo) and chemicals [48]. Hadad et al. [49] reported that gram-positive thermophilic soil bacterium, *Brevibacillus borstelensis*, could degrade branched-chain low density polyethylene, in combination with ultraviolet radiation. Yamano et al. [50] showed that *Pseudomonas* strains could degrade nylon polymers with hydrolytic processes.

Conclusion and Recommendations

The issue of plastic pollution is escalating on a yearly basis due to indiscriminate disposal practices by people and industries and inability of plastic wastes to degrade in the environment. Despite the existence of numerous interventions to resolve the issue, the problem still persists. Among the strategies elaborated, positive human behavioural change is highly recommended as it will provide a long lasting solution to the environmental problem. Biotechnology is at the infant stage and offers a promising and reliable approach to tackle plastic pollution that has prevailed in the world today.

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